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Tiered Aquatic Life Uses and Comparison of Biological-based Attainment/Impairment Measures: One vs. Two Organism Groups

Aquatic Life Use Attainment
Fact Sheet 2-CABB-03

Aknowledgements

We would like to acknowledge the biologists of Ohio EPA who collected much of the data used in this paper and contributed to the development and implementation of biocriteria in Ohio. The biologist include: Jeff DeShon, Marc Smith, Bernie Counts, Dave Altfater, Chuck Boucher, Brian Alsdorf, Bob Miltner, Jack Freda, Chuck McKnight, Mike Gray, Mike Bolton, Ray Beaumier, Dan Dudley, Dennis Mishne, and many other others. This work was supported by Cooperative Agreement X-97580701-0 between U.S. EPA and the Center for Applied Bioassessment and Biocriteria

Tiered Aquatic Life Uses

Aquatic Life Use Attainment at Stream Stations in Ohio: One vs. Two Organism Groups

Fish vs. Macroinvertebrate Measures of Aquatic Life Use Attainment

Background

The Clean Water Act (CWA) has an ultimate goal of achieving biological integrity in waters across the US. As engineering solutions to point sources have increasingly succeeded in reducing point sources of impairment, biological monitoring has been increasing used as an important way to assess and understand the complex affects of multiple stressors on the biological integrity goal of the CWA. An important part of a biological monitoring program is to understand the strength, weaknesses and sensitivities of various monitoring methods and how they may affect progress towards restoring biological conditions. As states progress to include biological criteria ("biocriteria") into their water quality standards, it is important to understand the sensitivities of the tools used to make assessments. The purpose of this fact sheet is to understand the sensitivities of fish and macroinvertebrate assessments that comprise Ohio's biocriteria to provide some insight for other States deciding on how to implement a biological monitoring program.

Ohio's Biocriteria

Ohio has pioneered the use of numerical biocriteria to judge the attainment or impairment of CWA goals. Numerical biological criteria in Ohio are based on multimetric biological indices including the Index of Biotic Integrity (IBI) and modified Index of Well-Being (MIwb), indices measuring the response of the fish community, and the Invertebrate Community Index (ICI), which measures the response of the macroinvertebrate community. The IBI and ICI are multimetric indices patterned after an original IBI described by Karr (1981) and Fausch et al. (1984). The ICI was developed by Ohio EPA (1987b) and further described by DeShon (1995). The MIwb is a measure of fish community abundance and diversity using numbers and weight information and is a modification of the original Index of Well-Being originally applied to fish community information from the Wabash River (Gammon 1976; Gammon et al. 1981). Performance expectations for the principal aquatic life uses in the Ohio WQS (Warmwater Habitat [WWH], Exceptional Warmwater Habitat [EWH], and Modified Warmwater Habitat [MWH]) were developed using the regional reference site approach (Hughes et al. 1986; Omernik 1987). This fits the practical definition of biological integrity as the biological performance of the natural habitats within a region (Karr and Dudley 1981).

Numerical endpoints are stratified by ecoregion, use designation, and stream or river size. These biological criteria codified in the Ohio Water Quality Standards (WQS; Ohio Administrative Code [OAC] 3745-1-07, Table 7-14). Three attainment status results are possible at each sampling location - Full, partial, or non-attainment. Full attainment means that all of the applicable indices meet the Ohio WQS biocriteria. Partial attainment means that one or more of the applicable indices fails to meet the biocriteria. Non-attainment means that none of the applicable indices meet the biocriteria or, for WWH and EWH streams, one of the organism groups reflects poor or very poor performance.

Previous Research

The choice of organism group in State monitoring programs has probably been a combination of available expertise, available of grant dollars to fund specific programs, and the usefulness of the organism group in determining impacts within a state. States universities with active research programs related to macroinvertebrate ecology will be more likely to have placed staff in resources agencies with such a background. The same can be said for fisheries work. Such a historical connection was strongest during the periods when biosurvey programs were beginning and research related to the strengths and weakness of approaches was minimal.

Recently more focus has been put on creating integrated monitoring toolboxes that have data on multiple organism groups, water chemistry, habitat, sediment chemistry, toxicity testing etc., to accurately assess waters and the myriad of complex stressors that occur in them. Many states, however, still focus primarily of a single organism group in their assessments (Davis ref), although more states have the capacity to collect data on two or even three groups where warranted (e.g., fish, macroinvertebrates, and algae).

Some work has been done to compare the relative sensitivities of different organism groups to various stressors. For example, Bryce and Hughes (2002) compared fish, macroinvertebrates, and bird assemblages in the Willamette Valley in Oregon and in the Mid-Appalachian highlands in their response to various human disturbance gradients. They found that although all groups agreed on the general levels of disturbance each group and metrics within each group responded most strongly to different disturbance types. For example, as might be expected, bird assemblages responded strongly to a gradient of riparian condition and macroinvertebrates responded strongly to substrate measures. Fish and macroinvertebrates both respond to gradients of urbanization across the U.S. as summarized by Wang and Lyons 2002). In Michigan, Lammert and Allan (1999) found differing responses between fish and macroinvertebrate communities to stressors with fish responding and macroinvertebrates responding more strongly to local habitat. Other workers have examined the responses of individual organism groups to stressors found in stream ecosystems, such as sedimentation (Berkman and Rabeni 199?),

Monitoring results have been the focus of more attention because of the consequences of listing impaired waters on lists like the 305(b) and 304(l) lists (now integrated). Given the importance and costs associated with programs like U.S.EPA's TMDL efforts, it is essential that the consequences of using a single vs. multiple

organism groups be recognized. If responses to degradation among organism groups are potentially large, then restoration and protection efforts driven by a single organism group could lead to the under-protection or at minimum an incomplete focus on the limiting stressors in TMDL efforts. The consequences and costs of using a single vs. multiple organism groups are likely to vary at least at a regional or ecoregional scale as the stressor regimes vary across the country. The purpose of this effort is to provide a retrospective analysis of the consequence of using one vs. two organism groups in Midwest streams in Ohio.

Ohio Data

As discussed above it is generally considered optimal to have multiple organism groups, when determining aquatic life use status because each group may have differing sensitivities to the stressors that can affect attainment of an aquatic life use. Ohio typically uses two organism groups in nearly all study areas, to determine aquatic life use status. Because Ohio uses Hester-Dendy multiple plate artificial substrates, the macroinvertebrates do not always strongly detect the signal for habitat loss, especially where degradation is local. Ohio considers this an advantage in distinguishing habitat vs. chemical stressors in the stressor identification process. This may exaggerate, however, the difference in comparing attainment decisions between one vs. two organism groups that we will present here, however, it still provides some insight into the usefulness and risks related to using a single vs. multiple organism groups which will need to be refine depending on the region and methods used.

The data used in this study is derived from Ohio's intensive survey studies, sampling of reference sites, and other miscellaneous studies. Fish and macroinvertebrate station locations may not match exactly, partly because fish data is collected along a transect of 150-500 depending on streams size while macroinvertebrate data, with the exception of a qualitative sampling of all available habitats, is a point sample where the sampling device was set (generally in flowing water of sufficient depth to ensure the device is underwater during the six week colonization period). Common station sample numbers were assigned on a case-by-case basis to all fish, macroinvertebrate, water column and sediment chemistry data that were considered equalivalent in their purpose and in the stressors and conditions affecting them. Data for this study was collected from 1979 to 2001.

Results and Discussion

Figure 1 contains pie charts containing the integrated attainment status using both organism groups and a re-analysis of the same stations assuming only fish data was available or assuming only quantitative macroinvertebrate data was available. The number of non-attaining waters (excluding partial attainment) were similar under all three scenarios, however, the proportion of waters fully attaining the appropriate use differed among the organism groups. The fewest waters attaining the aquatic life uses occurred when both organism groups were used. When only fish were used, the MIwb and IBI, two fish indices, disagreed on attainment status in 20.2% of the cases resulting in a partial attainment assessment. As defined, partial attainment cannot occur when only macroinvertebrates were used. Examination of stressors indicates

that part of the discrepancy between fish and macros measures is related to the greater sensitivity of fish to macro-habitat alterations. The use of an artificial substrate sampler provides a substrate for colonization and the macroinvertebrates do not respond as strong to a habitat stressor because of this. Conversely, in some small streams were flow over riffles is low or non-existant for parts of the summer, artificial substrate samples may underestimate the potential quality of the stream with regard to supporting aquatic life.

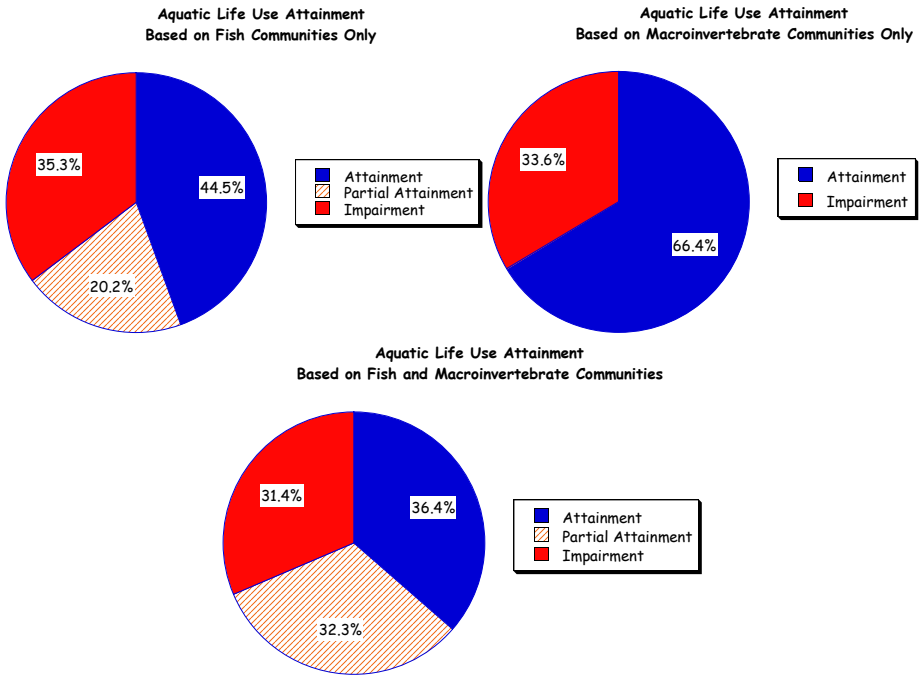
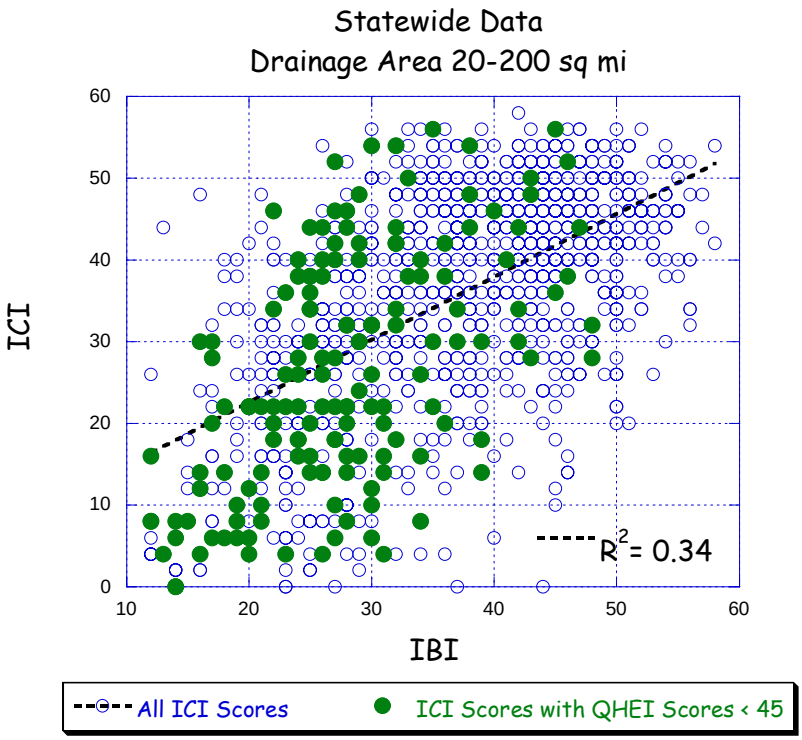


Figure 1 Aquatic life use attainment in Ohio streams in which fish community data (with IBI and MIwb) and quantitative macroinvertebrate data (ICI) were available in Ohio streams. Under the bottom scenario, both organism groups were used to determine aquatic life use status (current practice); on the top left only fish community data (IBI, MIwb) was used and in the top right only quantitative macroinvertebrate data (ICI) was used. Stations with biological data collected within summer period (June 15-Oct 15) from 1979 until 2001 in larger than headwater streams (20 sq mi) are included.

Figure 2 is a statewide plot of IBI vs. ICI at wadeable streams (20-200 sq mi) in Ohio. Point as solid points are those sites with QHEI values < 45. Note that although the relationship is positive there is a fair amount of variation related to the differential stressor responses of the two groups. The solid points indicate that macro-invertebrates are less strongly affected by habitat. For example, the solid points are less frequent (more scattered) at high IBI scores (none at an IBI > 46 or so), but more clustered and evenly distributed along the ICI axis. Biologist at Ohio EPA have documented other differential responses of fish and macroinvertebrates (as they are sampled) including fish being more sensitive to effects that occur in pool of large rivers and macroinvertebrates recovering in large rivers with good riffle quality more quickly. These difference are not a weakness in these indicators unless they will be used alone. Used together they paint a more complete picture. A very high correlation

between IBI and ICI would negate the need for one of the indices.


Statewide Data
Drainage Area 20-200 sq mi
ICI
IBI
60
50
40
30
20
10
0
10
20
30
40
50
60
R2 = 0.34
All ICI Scores
ICI Scores with QHEI Scores < 45

Aquatic Life Use Attainment Based on Fish: One Index vs. Two Indices

For streams greater than 20 sq mi of drainage area, Ohio uses both and IBI and a second index, the Modified Index of well-being (MIwb). Although the IBI is considered more sensitive to the range of stressors that affect Ohio streams, the MIwb provides information related to abundance, biomass, and evenness that proves useful in certain types of situations. For example, the MIwb generally recovers more quickly from traditional enrichment impacts which is useful in trend assessment and recovery studies. For certain types of impairments, for example episodic mine drainage affects, the MIwb reflects the long-term suppression of abundance and biomass from episodic impacts. In some of these situations, especially where good refugia are abundant, the IBI may overestimate recovery where richness and proportions of individuals have recolonized areas, but sufficient time has not elapsed to allow recovery to previous levels of abundance or biomass.

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